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ORIGINAL ARTICLE

Role of multi-slice CT angiography in the evaluation of conotruncal anomalies



Osama Lamie Nakhla *

Department of Radiodiagnosis, Faculty of medicine, Beni Suef University, Egypt

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KEYWORDS

Multi-slice ct angiography;
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Abstract *Purpose:* To assess and highlight the role of MSCT angiography in evaluation of extra-cardiac vascular abnormalities in conotruncal anomalies.

Methodology: This study included 39 patients (21 males and 18 females) with an age range of 29 days–21 years. All of these patients underwent MSCT angiography and echocardiography.

Results: The most common conotruncal anomaly detected in this study was pulmonary atresia with VSD accounting for approximately 33% of the cases. Out of the 39 examinations performed CT angiography added critical additional findings missed by echocardiography in 17 cases which is approximately 44% of the total number of studies performed. The Major CT Angiographic Findings Missed By Echocardiography were pulmonary artery stenosis 4 cases, MAPCAS 7 cases, PDA 2 cases, Aorto-pulmonary window one case. There was only 33% agreement between echocardiography and CT in delineation of MAPCAS which is of great importance in pre-operative evaluation of these patients.

Conclusion: The CT angiographic findings are of great additional value to echocardiographic findings specially in the evaluation of pulmonary artery anomalies and MAPCAS. MSCT imaging techniques for CHD are useful to evaluate diverse cardiovascular and airway abnormalities with improved accuracy.

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1. Introduction

Conotruncal heart defects are also known as outflow tract defects. Common types of conotruncal heart defects are truncus arteriosus, transposition of the great arteries, double outlet of the right ventricle, tetralogy of Fallot, pulmonary atresia

with ventricular septal defect, interrupted aortic arch and aortopulmonary window (1).

The traditional method of diagnosis of congenital heart disease has been catheter angiography. While effective in diagnosis, angiography is an invasive procedure. Evaluation of right and left sided defects may require both venous and arterial punctures (2).

Echocardiography (ECHO) is the mainstay of diagnosis of congenital heart disease. Its strength includes an absence of radiation, the ability to evaluate intra-cardiac structure and function and the ability to perform hemodynamic assessment.

* Tel.: +20 1278003550.

E-mail addresses: osamaradio@yahoo.com, osamaradio@gmail.com

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However, it is limited in the evaluation of certain portions of the aorta (particularly the ascending aorta and the transverse arch), the distal pulmonary arteries, the right ventricle, and the pulmonary veins (3).

The recent developments in CT techniques are characterized by faster speed, longer anatomic coverage, a more flexible ECG-synchronized scan and a lower radiation dose. These advances have noticeably increased the cardiac applications of CT. This increasing role of CT also includes the evaluation of congenital heart disease (4–6). Minimization of the radiation exposure delivered by CT is an important issue particularly for children (7,8). Various dose reduction techniques are currently available for cardiac CT as a result of the efforts to reduce the CT dose (9,10).

2. Patients and methods

This study included 39 patients (21 males and 18 females with age ranges from 29 days to 21 years) suspected or diagnosed of having conotruncal anomalies on examination and echocardiography. Patients were examined in the period from (October-2010) to (February-2013). Echocardiography examination was performed for all patients prior to CT Angiography. All patients with suspected conotruncal anomalies were referred in order to perform further CT angiography examination of the heart and thoracic vessels.

2.1. Patient's preparation

History taking, Checking renal functions, Fasting for at least 2–3 h was required prior to the examination; proper hydration was advised for at least 4 h before contrast injection.

2.2. Patient's sedation

Mild or no sedation was used in most cases. General anesthesia is infrequently needed. Oral and rectal chloral hydrate was used if necessary. Sometimes IV diazepam was used with a dose of 1 ml/kg only in few cases.

2.3. Contrast media

Nonionic contrast medium was administrated at a dose of 1–2 mL/kg with 240–320 mg/mL iodine concentration through a 20 or 22 G intravenous catheter in the patient's arm or leg with power dual injector at a rate of 1.5–4 mL/s and saline chaser, Power injector administration of IV contrast material is preferred to hand injection because homogeneous intravascular enhancement can be achieved. However manual injection was used in some cases (when total volumes needed less than 20 ml).

An empiric scan delay technique between 7 and 15s from the onset of contrast administration to start of scan acquisition determined according to the weight of the patient and congenital anomaly under question. We did not perform automatic bolus tracking as in the majority of cases there was left to right shunts e.g. ASD, VSD and PDA making the process difficult and time consuming.

2.4. MDCTA protocol

- Most of our patients (31 patients) included in this study were examined by dual-source CT system (SOMATOM Definition, Siemens, Forchheim, Germany). Only seven patients were examined by bright speed 8 detectors CT machine (GE, Phillips, Malaysia).
- Low radiation dose technique was used according to the patient weight. Twenty to 30 mAs was used for those under three years old; 40–100 mAs for those weighted 25–55 kg; 100–140 mAs for patients weighted > 55 kg; 60 kV for patients weighted < 45 kg; and 100–120 kV for those weighted ≥ 45 kg.
- The slice thickness was 1–2.5 mm with 50% reconstruction overlap and a pitch of one. Total exposure time about 7 s.
- The patient lies on the CT table in supine position. The scan started at the level of thoracic inlet to include the proximal parts of the carotid and subclavian arteries and ended below the diaphragm.
- **ECG gating** was performed in cases above 18 years of age and in case of suspected aortopulmonary windows. In the rest of the cases ECG gating was not performed to avoid unnecessary excess radiation exposure.
- **Multi-phase examination** of the heart is then performed. Sequential series of images in the midvenous, midarterial and delayed phases of enhancement are taken to ensure opacification of both sides of the heart and all extra-cardiac vessels.

Table 1 Echocardiography versus CT in detecting Different types of aortic abnormality.

Aortic abnormality	ECHO	CT
Over-riding	8	8
Right side AA	2	3
Coarctation	3	2
IAA	2	3

Table 2 Number of patients according to type of pulmonary artery abnormality by echocardiography and CTA.

Abnormality	ECHO	CT
Atresia	7	13
Stenosis	2	6
Non-confluent	1	3
LPA agenesis	0	1
NON-visualized	6	2

Table 3 Number of cases of aorto-pulmonary connection by echocardiography and CTA.

AORTO-pulmonary connection	ECHO	CT
MAPCAS	4	11
PDA	7	9
Truncus arteriosus	1	2
Aorto-pulmonary window	1	2

- **Image processing and interpretation:** The acquired axial images were reconstructed in sagittal and coronal planes. Furthermore a variety of high quality 2D reformatted and 3D reconstructed images are generated that aid in the understanding of complex cardiovascular anatomy. A combination of three dimensional *maximum intensity projections (MIP)*, *volume rendering (VR)*, *multiplanar (MPR)* and *curved planer reformations (CPR)* were created at different angles of views.

The images consisted of all anatomic structures of thorax including aorta and its branches, pulmonary artery and its branches, pulmonary veins and types of their returns, superior vena cava (SVC), inferior vena cava (IVC) and other veins, cardiac chambers, pericardium, pulmonary parenchyma, pleura, trachea and its bifurcation and major bronchus, ribs, abdominal organs, abdominal vessels and visceral situs. Image sets were systematically interpreted and the results were compared with echocardiography.

3. Results

The most common conotruncal anomaly detected in this study was pulmonary atresia with VSD accounting for

approximately 33% of the cases, followed by transposition of great vessels (TOG) accounting for approximately 22%. The detected abnormalities were classified into three major groups (aortic abnormalities, pulmonary abnormalities and aortopulmonary connections), the CT findings were compared with echocardiography.

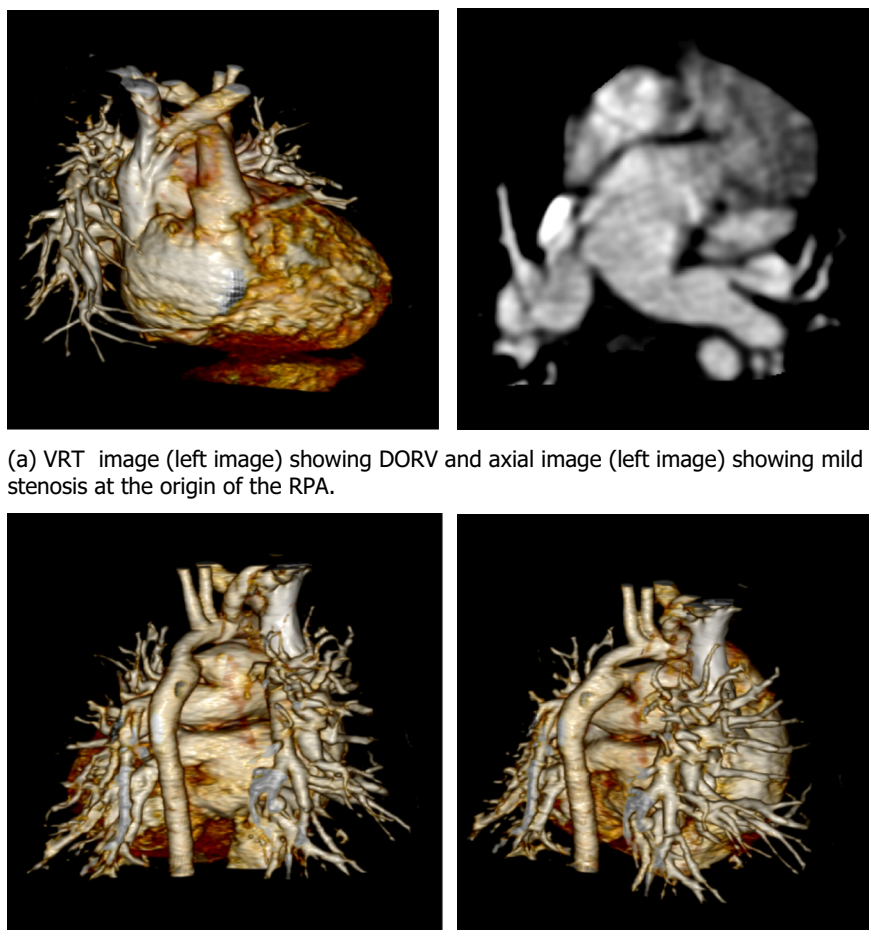
3.1. Aortic abnormalities

The detected aortic abnormalities in this study were right side aortic arch, interrupted aortic arch, coarctation of the aorta and over-riding aorta. Echocardiographic and CT findings are compared in [Table 1](#).

3.2. Pulmonary artery abnormalities

Non-visualization of the pulmonary artery was considered as a pulmonary vascular abnormality

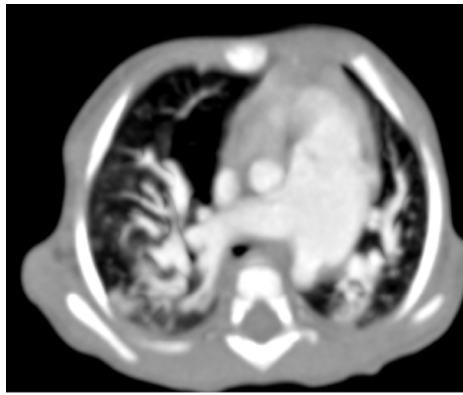
Regarding the cases of pulmonary artery stenosis, echocardiography failed to detect four cases of stenosis in the left pulmonary artery, likely due to technical difficulties, however it displayed 100% agreement with CT in right pulmonary artery stenosis ([Table 2](#)).



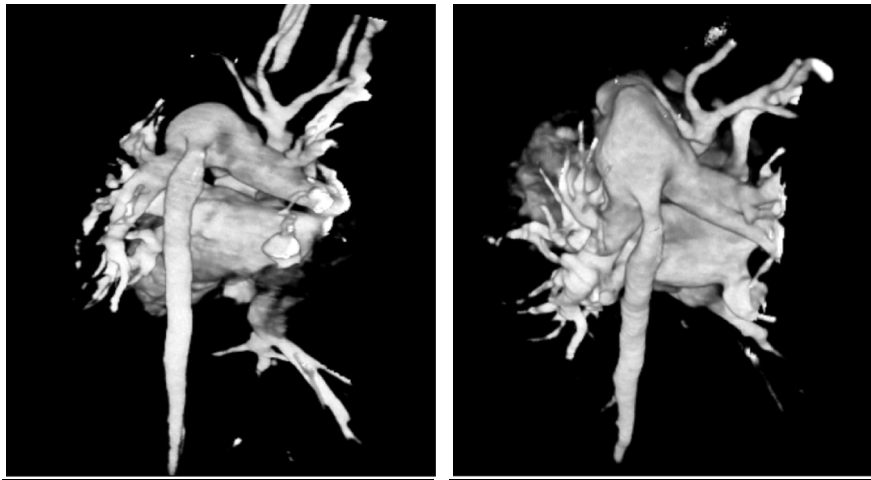
(a) VRT image (left image) showing DORV and axial image (left image) showing mild stenosis at the origin of the RPA.

(b) VRT images showing hypoplastic arch with large PDA supplying the descending aorta.

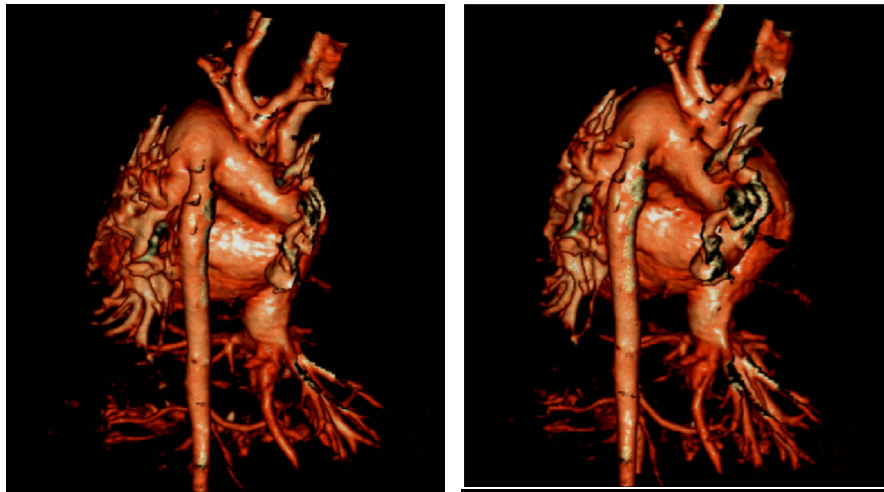
Fig. 1 2 years old male with cyanosis, feeding troubles and finger clubbing.



(a) axial image showed PDA supplying the descending aorta.



(b) VRT black & white image posterior view (Left image) superior view (Right image). IAA with PDA supplying the descending aorta.



(c) VRT colour image posterior view (Left image) oblique view (Right image). IAA with PDA supplying the descending aorta.

Fig. 2 4 months old female, complains of shortness of breath and repeated attacks of chest infection.

3.3. Aorto-pulmonary connections, [Table 3](#)

These were sub-classified into PDA, MAPCAS, truncus arteriosus and aorto-pulmonary windows. There was only 36% agreement between echocardiography and CT in delineation of MAPCAS which is of great importance in pre-operative evaluation of these patients.

4. Discussion

Advances in surgical technique, anesthesia, and perioperative care have significantly improved the surgical success rate and life expectancy in patients with congenital heart disease (CHD). Echocardiography is often the initial imaging technique, but it may be limited by lack of an adequate acoustic window and more importantly suboptimal depiction of the extra-cardiac vasculature. Evaluation with magnetic resonance (MR) may also be limited in uncooperative patients and can require sedation of younger patients. Multidetector computed tomography (MDCT), because of its wide availability, short acquisition time, high spatial resolution, improved temporal resolution, and isotropic imaging, is an attractive alternative method. Because of the potential risk of ionizing radiation

involved with CT examinations in this typically young population, great care must be taken to use the lowest dose possible allowing diagnostic assessment ([6,11,12](#)).

Recent technical advances in multi-slice CT scan technology allowed reduction of motion artifacts and postprocessing of thinner sections to transform these thin axial sections into two dimensional images in the coronal and sagittal planes and into three dimensional images. Dual-source CT scanner generation (two X-ray sources and two detectors at the same time i.e. 128-slice CT scanners and more) provided substantially improved scan speed and temporal resolution for CT scans of the heart compared to the 64-slice CT scanners ([13](#)).

In this study the CTA examination was carried out utilizing a low radiation dose protocol used according to the patient weight. Twenty to 30 mAs was used for those under three years old; 40–100 mAs for those weighted 25–55 kg; 100–140 mAs for patients weighted > 55 kg; 60 kV for patients weighted < 45 kg; and 100–120 kV for those weighted ≥ 45 kg. Our scan doses agreed with Hu et al., 2008 ([14](#)) and Tsai et al., 2008 ([15](#)) as they stated that the neonatal cardiac CT dose is around 1.12–1.76 mSv for the non-gated technique and 2.17–3.41 mSv for the gated technique. ECG-pulsing is probably an excellent technique for cardiac CT in adults with slow heart rates, but not for cardiac CT in neonates.

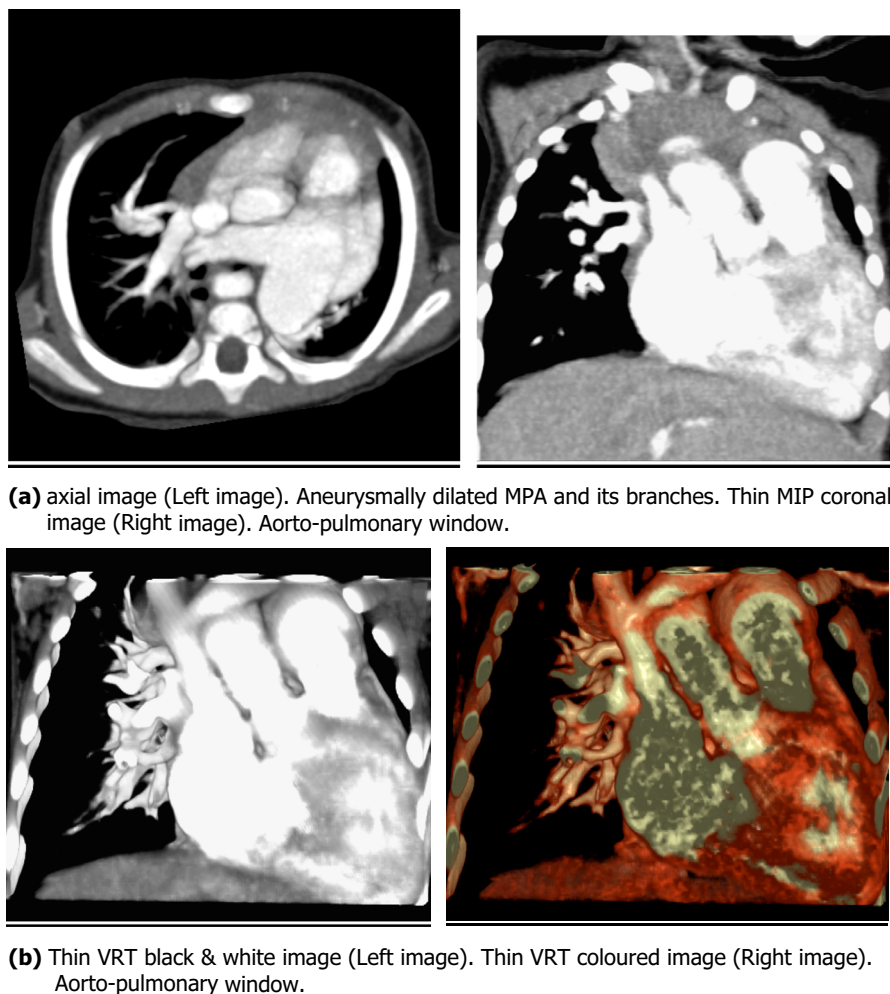


Fig. 3 6 months old female complains of shortness of breath and no cyanosis.

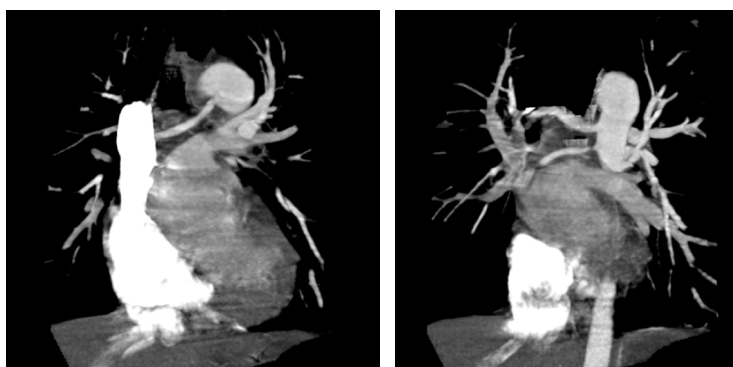
In our study we injected contrast media at a rate of 1 to 2 ml/kg which agreed with Frush & Herlong, 2005 (16). No significant complications were encountered during or after the CT angiographic procedure in any of the cases.

Aortic abnormalities were detected in this study in 15 patients in echocardiography and 16 patients in CTA. There is disagreement between echocardiography and CT in approximately 7% of the cases. This disagreement is due to misdiagnosis of a case interrupted aortic arch (IAA) as coarctation which was confidently diagnosed by CT as IAA as well as missing a

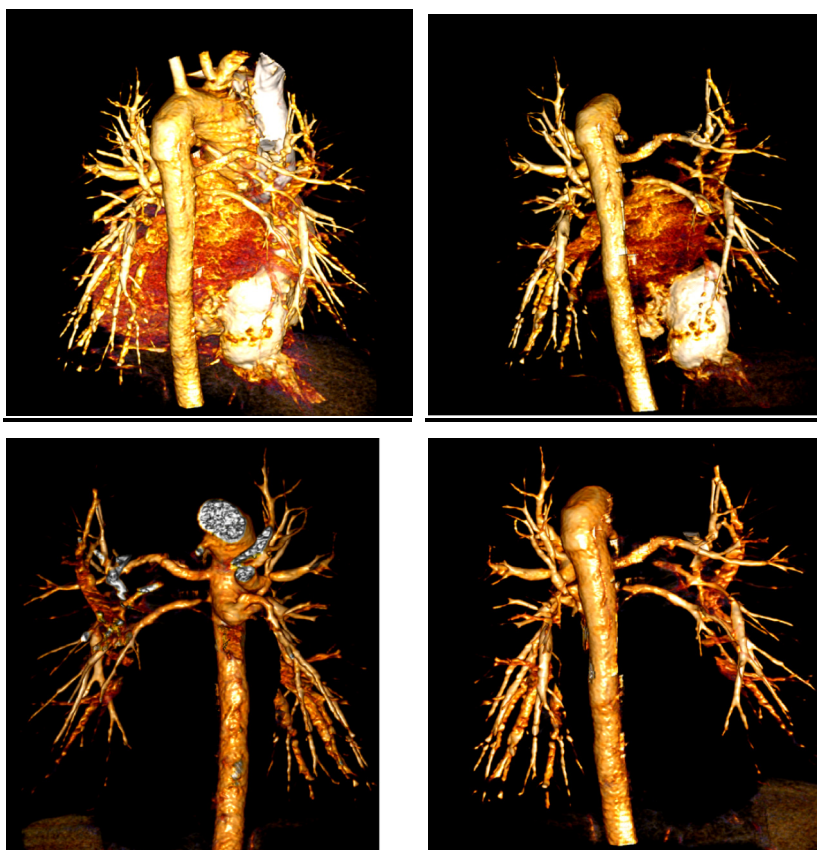
right sided aortic arch by echo likely due to technical limitation of echocardiography.

Krishnamurthy, 2009 (17) reported the reliability of MDCT angiography and three-dimensional (3-D) reconstruction in patients with coarctation of the aorta. The sensitivity of MDCT diagnosis for coarctation of the aorta was 100%, which was higher than that of echocardiography (87.5%).

In this study marked discrepancy was noted between the echocardiographic and CT findings regarding pulmonary artery abnormalities. Pulmonary artery abnormalities were



(a) Thin VRT images showing bilateral MAPCAs with stenosis at the origin of the third right MAPCA.



(b) VRT images showing bilateral MAPCAs with stenosis at the origin of the third right MAPCA.

Fig. 4 7 year old female, complains of cyanosis, shortness of breath, and repeated attacks of chest infection

detected in 16 patients in echocardiography and confidently diagnosed by CT in 25 patients.

Four of the six cases in which the pulmonary arterial tree was not visualized were false negative and only two were false positive. The commonest causes of non-visualization were technical difficulties and non-confluent pulmonary arteries.

Goo et al., 2003 (4) reported that CT angiography is useful in assessment of pulmonary arteries especially in cases of Tetralogy of Fallot and pulmonary atresia. This is demonstrated by the ability of CT to identify all sources of pulmonary blood flow (native pulmonary arteries and aortopulmonary collaterals), as well as identifying which segments of lung has dual blood supply, which is considered major goals in these patients. Determining the presence and size of native pulmonary arteries when findings are uncertain with echocardiography (small or non-confluent pulmonary arteries such as in Tetralogy of Fallot with pulmonary atresia).

Total agreement (100%) between echocardiography and CT in diagnosing right pulmonary artery stenosis was observed with total disagreement (100%) detected as regards left pulmonary artery stenosis. This is explained by the fact of small acoustic window and difficult orientation and delineation of the left pulmonary arteries during echocardiography.

Echocardiography missed one case of aorto-pulmonary window and another case of truncus arteriosus resulting in 50% agreement with CT findings which confidently depicted both of them.

In cases of major aorto-pulmonary collateral arteries (MAPCAS) there were seven false negative cases in which MAPCAS were not detected by echocardiography resulting in only 36% agreement with CT.

In patients with pulmonary atresia with ventricular septal defect, major aorto-pulmonary collateral arteries (MAPCA) often originate from the origin of the descending aorta. It is essential to determine the size and spatial relationship of these arteries when planning surgical intervention. Thin collimation slices are of value as it provides high-resolution images (18).

In our study some CT angiographic findings proved to be of great additional value to echocardiographic findings. Out of the 39 examinations performed CT angiography added critical additional findings missed by echocardiography in 17 cases which is approximately 44% of the total number of studies performed. The most common major CT findings were observed in the areas of pulmonary arterial abnormalities, major aorto-pulmonary collateral delineation, lung and tracheo-bronchial associated findings. In cases of pulmonary atresia demonstration of MAPCAs by CTA only represented approximately 33% of the major CT findings missed by echocardiography. These invaluable CT data had a significant impact on the pre-operative surgical planning and prognostic outcome in these patients with conotruncal and pulmonary venous anomalies.

In 2007 Leschka et al. (6) concluded that although echocardiography is the method of choice for diagnosing the vast majority of congenital cardiac abnormalities, CT plays an increasing complementary role by providing objective and accurate morphologic and functional information and is useful for detecting extracardiac abnormalities thus helping in pre-operative planning and postoperative assessment of congenital heart disease patients.

5. Conclusion

With MSCTA confident detection and exclusion of extra-cardiac vascular abnormalities was possible and when the abnormality was present high level of accuracy of its anatomic description was achieved. Multislice CT angiography (MSCTA) affords several advantages compared with echocardiography (see Figs. 1–4).

Conflict of interest

None declared.

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